

**EMISSIONS FROM AN ELECTRICAL POWER GENERATING UNIT
(PITTSBURG UNIT UNIT #6)**

Source Test Report

for the

2000 CENTRAL CALIFORNIA OZONE STUDY

May 28, 2002

Prepared for:

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APPENDIX: Sampling/Analytical Data and Calculations

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BACKGROUND

The University of California, Riverside, Bourns College of Engineering-Center for Environmental Research and Technology (CE-CERT) has conducted the following emissions testing and analyses:

Report No: 02-AP-20934-005-DFR

For: 2000 Central California Ozone Study

Purpose: To assess a variety of emissions from a power generating unit.

Tested At: Pittsburgh, CA

Test Date: October 20, 2000

Draft Report: May 28, 2002

Final Report: Due after receipt of comments and recommendations

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1.0 INTRODUCTION

As part of the 2000 Central California Ozone Study, the University of California, Riverside, Bourns College of Engineering—Center for Environmental Research and Technology (CE-CERT) was contracted to perform field testing at up to five stationary gas-fired combustion power generation facilities. CE-CERT was able to complete testing at two of the facilities before the onset of the California energy crisis, which impaired access to additional facilities. This report details the testing conducted at the Southern Energy California Unit #6 in Pittsburg, CA.

Results from the field testing include flow rates, temperatures, and moisture content of effluent streams as well as emissions concentrations and mass flow rates of CO, CO₂, NO, NO₂, PM₁₀, aldehydes and ketones, toxics such as chlorinated hydrocarbons, and C₁-C₄ hydrocarbons.

Based on previously reported emissions results, CE-CERT acquired appropriate calibration gas standards for emissions analyzers and installed them in a field testing vehicle. The portable gaseous emissions analyzer, particulate sampling trains, and integrated gaseous sampling systems were assembled and transported to the site.

Three complete source tests were performed at the Pittsburg facility over the course of one day. Testing included measurements of flow parameters and pollutant emissions concentrations. Measurement methods followed established source testing methods by the U.S. Environmental Protection Agency (EPA), California Air Resources Board (ARB), and the South Coast Air Quality Management District (SCAQMD). For determination of velocities and flow rates, stack traverses were performed with a Pitot tube and thermocouple. PM₁₀ and moisture content samples were acquired through traverse sampling using a Method 5-style sampling train. CO and CO₂ emissions concentrations were measured continuously

using non-dispersive infrared detection (NDIR). NO, NO₂, and O₂ concentrations were measured continuously using electrochemical detection. Integrated samples were obtained through cartridges for aldehyde determinations, and into Summa[®] canisters for air toxics determinations. Integrated gaseous samples were drawn into Tedlar[®] bags for C₁ – C₄ analyses. A set of three complete test runs was performed at the facility. Upon completion of the third run, the PM₁₀ samples and integrated bag samples were immediately transported by vehicle to the laboratories for analyses.

This report includes a description of the site and sampling locations, process operating parameters, emissions concentrations, and mass emissions rates.

2.0 SAMPLING AND ANALYTICAL PROCEDURES

2.1 Velocity, Moisture, and Flow Determination

Temperatures, velocities, and flow rates in the exhaust duct were determined using ARB Methods 1, 2 and 3.¹ The methods involve using an “S” type Pitot tube and thermocouple assembly to traverse the exhaust duct across a predetermined number of points, taking temperature and differential pressure measurements at each point. Moisture content in the effluent was determined gravimetrically using ARB Method 4.¹ These results are then used in combination with the average gas density and stack cross sectional area to determine exhaust flow rates.

2.2 Particulate Matter Method

For determination of total PM₁₀, the exhaust stream was sampled isokinetically following SCAQMD Method 5.1.² An integrated sample for each test was acquired over a minimum of 72 minutes. Each sample was extracted from the exhaust duct through a stainless steel nozzle and probe, impingers immersed in an ice bath, and a tared 0.45 micron Gelman quartz fiber filter located downstream of the last impinger. An additional straight tube impinger (empty bubbler) was placed at the front of each sampling train (Figure 1). The sample train was analyzed according to a modified SCAQMD Method 5.1. After sampling, the filter was removed and placed in a desiccator until completely dry. Following drying, the filter was weighed to determine the fraction of sample acquired on the filter. The probe, nozzle, sampling lines, and impingers were washed with deionized water and methylene chloride, and the washing solutions were combined with the impinger solutions. The combined solution was extracted with methylene chloride. The aqueous fraction was heated to boil off water, and the organic fraction was allowed to evaporate at room temperature. Residues from both fractions were weighed and combined with the sample weight from the filter to determine the total particulate sample weight. Samples were stored at 4 °C until analyzed at the CE-CERT laboratory.

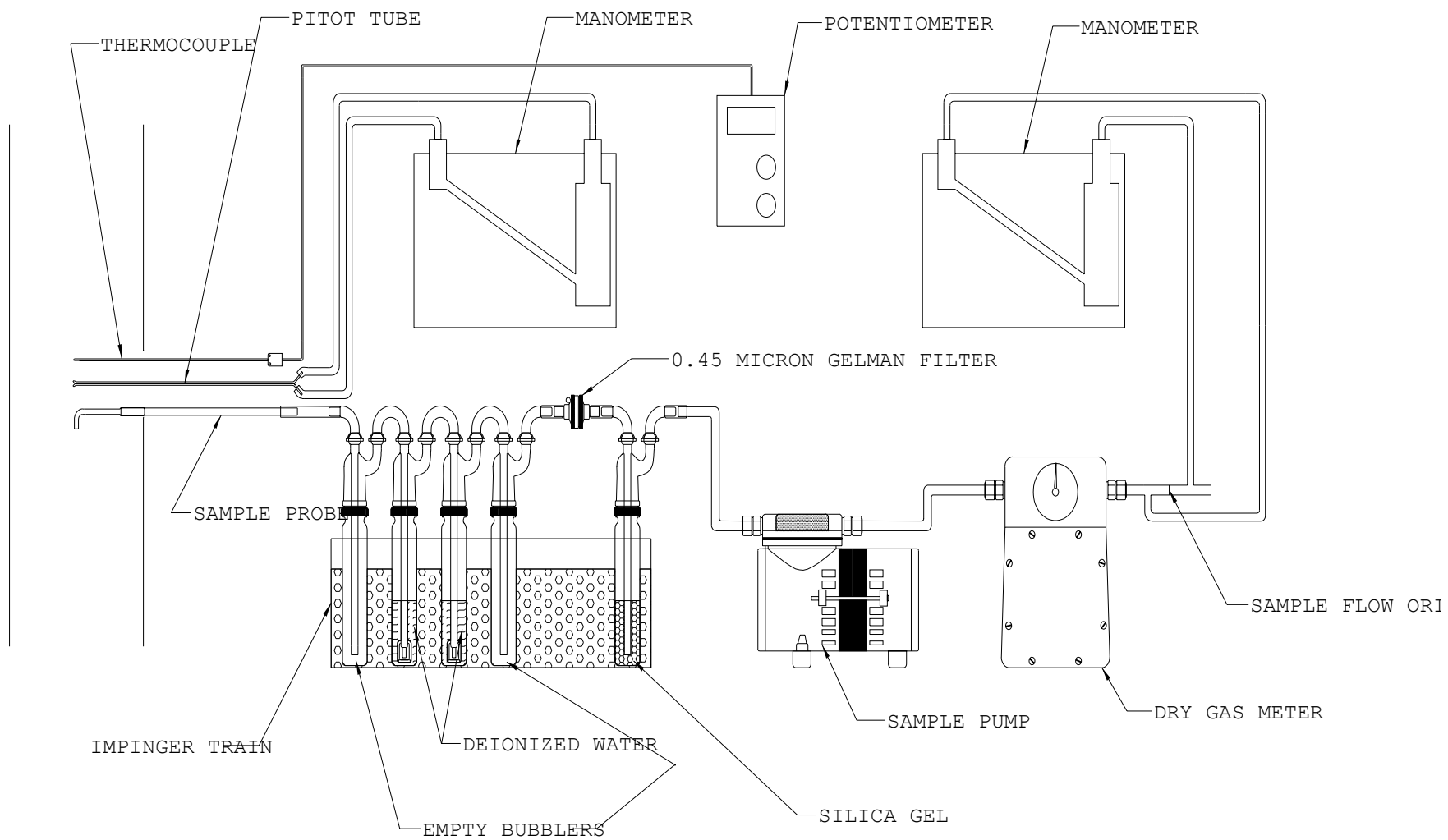


Figure 1. Particulate Matter Sampling System.

2.3 Aldehyde Method

A continuous sample was extracted from the exhaust stream through the sample conditioning system shown in Figure 2 during each test run. The conditioning system consisted of a miniature sampling train, including a single in-stack nozzle (facing downstream), a stainless steel probe, empty mini-impingers (for moisture knockout) in an ice bath, and a 0.45 micron pore size Gelman paper filter. The sample stream was drawn through the conditioning system and a cartridges containing crystalline 2,4-dinitrophenylhydrazine (DNPH) impregnated on a C-18 sorbent. The sample flow rate was set to approximately 1 liter per minute and measured with a calibrated dry gas meter. Analyses of the cartridges were performed by Performance Analytical according to EPA Compendium Method TO-11A.³ The DNPH cartridges were extracted with acetonitrile and analyzed for aldehyde and ketone derivatives using high performance liquid chromatography (HPLC). Table 1 shows the compounds that were quantified by this analysis. Mass emissions of individual carbonyl species were determined from analyzed concentrations, sample volume, and effluent volumetric flow rate.

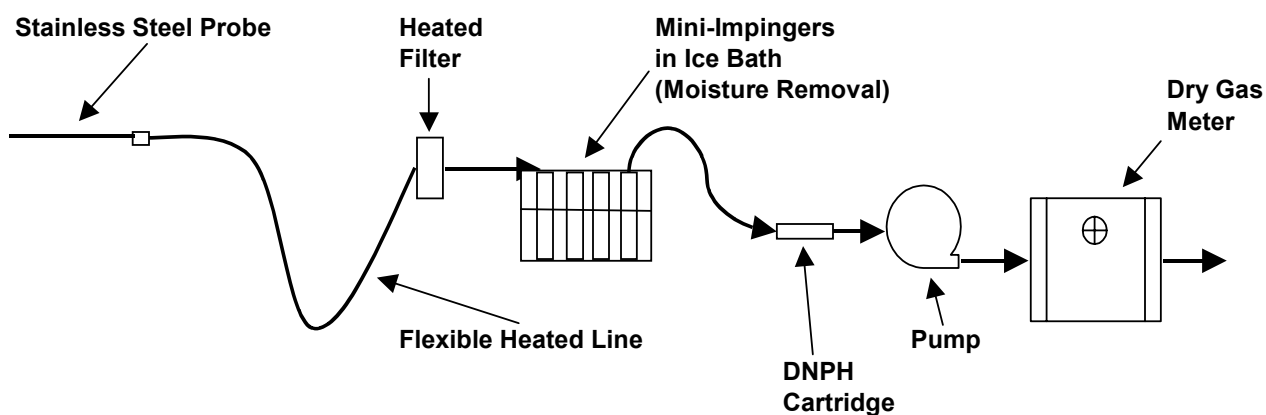


Figure 2. Aldehyde Sampling System.

Table 1. Aldehyde and Ketones Quantified.

Formaldehyde
Acetaldehyde
Acetone
Acrolein
Propionaldehyde
Crotonaldehyde
Butyraldehyde
Benzaldehyde
Isovaleraldehyde
Valeraldehyde
<i>o</i> -Tolualdehyde
<i>m</i> and <i>p</i> -Tolualdehyde
Hexaldehyde
2,5-Dimethyl Benzaldehyde

2.4 Air Toxics Method

A continuous sample was extracted from the exhaust stream through the sample conditioning system shown in Figure 3 during each test run. As above, the conditioning system consisted of a miniature sampling train, including a single in-stack nozzle (facing downstream), a stainless steel probe, empty mini-impingers (for moisture knockout) in an ice bath, and a 0.45 micron pore size Gelman paper filter. The sample stream was drawn through the conditioning system and a Teflon pump with Viton valves and O-rings. An evacuated

Summa canister was attached downstream of the pump via a “T” connector, allowing for the

continuous purge of sample prior to toxics sampling. The canister was equipped with a pre-set flow controller (0.8 liter/hour). The valve was opened, allowing sample into each canister for approximately 1 hour. The Summa canister samples were analyzed by combined gas chromatography/mass spectroscopy (GC/MS) for volatile organic compounds. The analyses were performed by Performance Analytical according to EPA Compendium Method TO-14A,⁴ utilizing a direct cryogenic trapping technique. The analytical system comprised a Hewlett-Packard Model 5973 GC/MS/DS interfaced to an Entech 7100 automated whole air inlet system/cryogenic concentrator. A 100% Dimethylpolysiloxane capillary column (RT_x-1, Restek Corporation, Bellefonte, PA) was used to achieve chromatographic separation. Table 2 shows the list of target compounds.

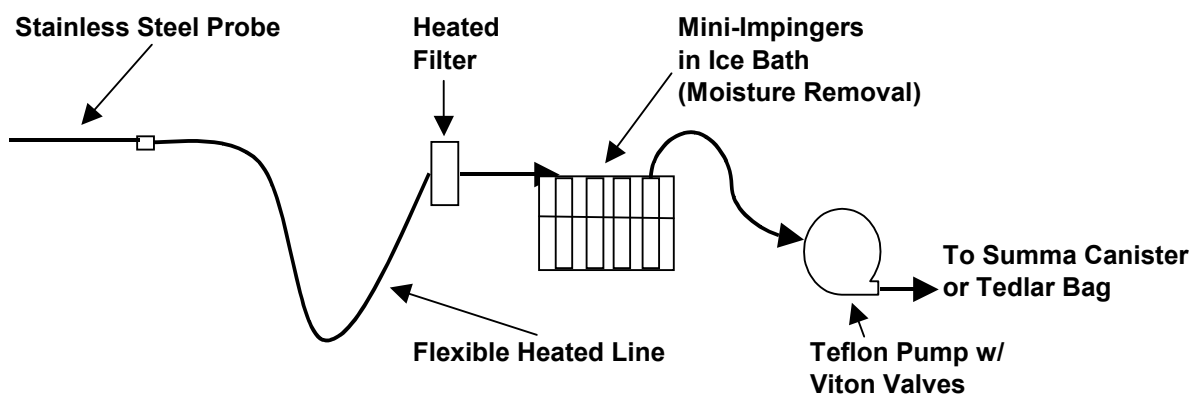


Figure 3. Air Toxics/C₁-C₄ Sampling System.

Table 2. Compounds Identified by TO-14A Analysis.

Chloromethane	Bromodichloromethane
Vinyl Chloride	Trichloroethene
Bromomethane	<i>cis</i> -1,3-Dichloropropene
Chloroethane	4-Methyl-2-Pentanone
Acetone	<i>trans</i> -1,3-Dichloropropene
Trichlorofluoromethane	1,1,2-Trichloroethane
1,1-Dichloroethene	Toluene
Methylene Chloride	2-Hexanone
Trichlorotrofluoroethane	Dibromochloromethane
Carbon Disulfide	1,2-Dibromoethane
<i>trans</i> -1,2-Dichloroethene	Tetrachloroethene
1,1-Dichloroethane	Chlorobenzene
Methyl <i>tert</i> -Butyl Ether	Ethylbenzene
Vinyl Acetate	<i>m</i> & <i>p</i> -Xylene
2-Butanone (MEK)	Bromoform
<i>cis</i> -1,2-Dichloroethene	Styrene
Chloroform	<i>o</i> -Xylene
1,2-Dichloroethane	1,1,2,2-Tetrachloroethane
1,1,1-Trichloroethane	1,3-Dichlorobenzene
Benzene	1,4-Dichlorobenzene
Carbon Tetrachloride	1,2-Dichlorobenzene
1,2-Dichloromethane	

2.5 Gas Concentration Methods

A Testo model 360 analyzer was used to measure gas concentrations. Carbon monoxide and carbon dioxide concentrations were continuously monitored and recorded using a non-dispersive infrared (NDIR) detector. Nitric oxide, nitrogen dioxide, and oxygen concentrations were continuously monitored and recorded using electrochemical detection cells. The sampling, conditioning, and analyses of CO, CO₂, NO, NO₂, and O₂ followed ARB Method 100. A schematic of the continuous gaseous analyzer system is shown in Figure 4. For C₁-C₄ gas determination, an integrated sample was extracted from the exhaust stream through the sample conditioning system shown in Figure 3 during each test run. A Tedlar bag was attached downstream of the pump via a “T” connector, allowing for the continuous purge of sample prior to gas sampling. The bag valve was opened, allowing sample into the bag over a 4 to 6 minute period. The Tedlar bag samples were analyzed at the CE-CERT laboratory by gas chromatography for C₁ – C₄ organic compounds using the Auto/Oil Standard Conditions.⁵ The analyses were performed utilizing a fixed response factor.

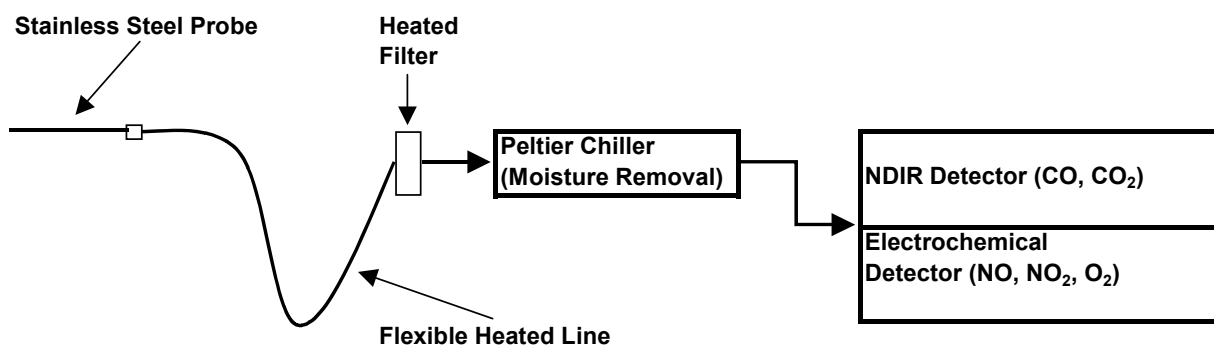


Figure 4. Continuous Gas Sampling System.

3.0 PROCESS DESCRIPTION

The process tested was Unit #6, a natural gas-fired steam turbine used to produce electricity. The unit is owned and operated by Southern Energy California, and is located in Pittsburg, California. It has a generating capability of 400 MW, and was operating at approximately 69% of capacity during testing.

The exhaust effluent is ducted from the generator building to a large vertical stack via two large symmetrical horizontal ducts. The sampling ports are located in each of the horizontal ducts, upstream of the merge to the vertical stack (Figure 5). The two exhaust ducts are rectangular in geometry, with 4 sampling ports in each duct.

Twelve sample traverse points were selected for testing (3 per port) in each of the two exhaust ducts. The location of the sampling points were determined using ARB Methods 1 and 2 (Figure 6).

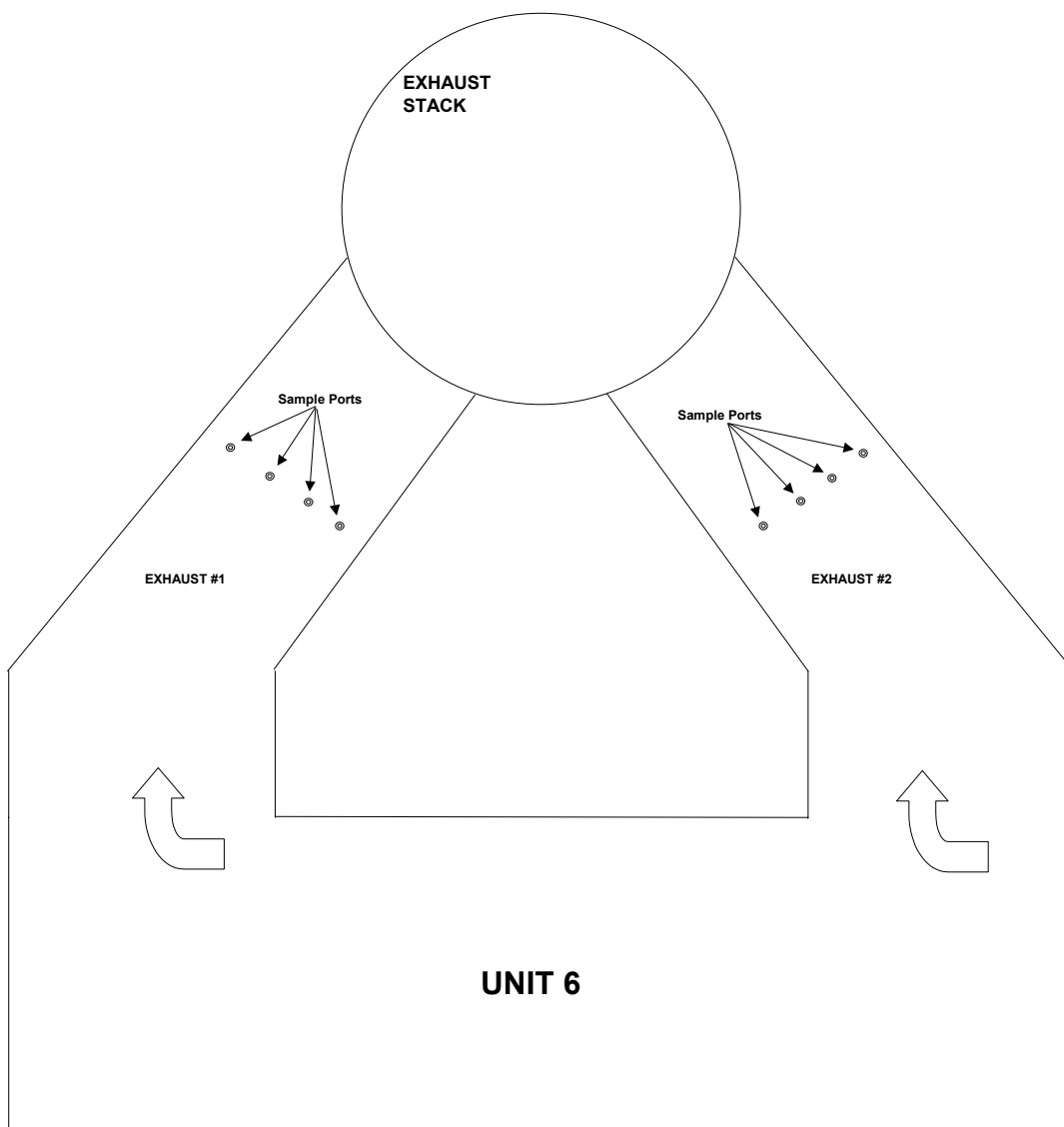


Figure 5. Pittsburgh Unit #6 Exhaust System (Top View).

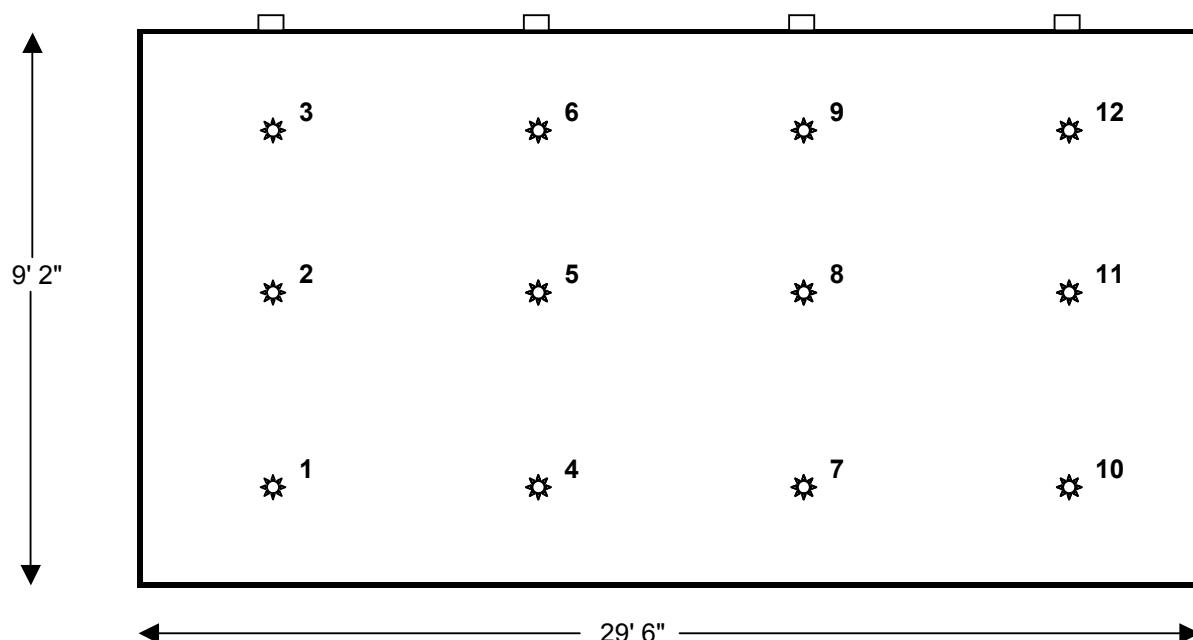


Figure 6. Pittsburgh Unit #6 Sample Points (Cross-Section).

4.0 RESULTS

Two identical test runs were performed in exhaust duct #1, and a single third run was performed in the symmetrical exhaust duct #2 using the procedures described in Section 2.0. The exhaust flow rates, emission concentrations, and mass emission rates were calculated from the data collected during each run for species that were detected in at least one sample. The appendix includes all analysis data.

Table 3 summarizes the criteria pollutant and fixed gas results for the three test runs, along with the average concentrations and mass flow rates for the entire test period.

Table 3. Criteria Pollutant and Fixed Gas Emissions.

Compound Name	Concentration (ppm CO, NO, NO ₂ ; %CO ₂ , O ₂)				Calculated Mass Flow Rate (lb/hr)				
	run #1	run #2	run #3	AVG	run #1	run #2	run #3	AVG	SD
CO	10.54	2.06	7.21	6.60	14.39	3.25	9.88	9.17	5.61
CO ₂	8.48	8.97	8.37	8.61	1.82E+05	2.22E+05	1.80E+05	1.95E+05	2.37E+04
O ₂	2.64	2.23	3.61	2.83	4.12E+04	4.01E+04	5.65E+04	4.59E+04	9.18E+03
NO	33.82	33.68	29.99	32.50	49.46	56.84	44.01	50.11	6.44
NO ₂	1.56	0.95	1.00	1.17	3.50	2.46	2.25	2.73	0.67
PM ₁₀	N/A	N/A	N/A	N/A	4.72	3.72	11.23	6.55	4.08

Pittsburg Unit #6 (10/20/00)

Table 4 summarizes the aldehyde results for the three test runs, along with the average concentrations and mass flow rates for the entire test period. All concentrations were corrected for the method blank. Acetone was not reported since large amounts were observed on the method blank.

Table 4. Aldehyde Emissions.

Compound Name	Measured Concentration (ppb)				Calculated Mass Flow Rate (g/hr)				
	run #1	run #2	run #3	AVG	run #1	run #2	run #3	AVG	SD
Formaldehyde	0.00	0.00	2.27	0.76	0.00	0.00	1.51	0.50	0.87
Acetaldehyde	13.71	6.14	5.28	8.38	13.36	6.91	5.17	8.48	4.32
Propionaldehyde	2.33	1.41	1.33	1.69	2.99	2.09	1.71	2.26	0.66
Benzaldehyde	0.00	0.02	0.00	0.01	0.00	0.06	0.00	0.02	0.04
Valeraldehyde	0.00	0.35	0.36	0.24	0.00	0.77	0.69	0.49	0.43

Pittsburg Unit #6 (10/20/00)

Table 5 summarizes the air toxic results for the three test runs, along with the average concentrations and mass flow rates for the entire test period.

Table 5. Air Toxic Emissions.

Compound Name	Measured Concentration (ppb)				Calculated Mass Flow Rate (g/hr)				
	run #1	run #2	run #3	AVG	run #1	run #2	run #3	AVG	SD
Chloromethane	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acetone	4.60	9.20	4.60	6.13	5.91	11.87	6.82	8.20	3.21
Methylene Chloride	0.00	2.20	0.00	0.73	0.00	4.15	0.00	1.38	2.40
Carbon Disulfide	0.00	3.00	0.00	1.00	0.00	5.07	0.00	1.69	2.93
Chloroform	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Toluene	2.50	1.60	0.00	1.37	5.10	3.27	0.00	2.79	2.58

Pittsburg Unit #6 (10/20/00)

Table 6 summarizes the C₁ – C₄ gas results for the three test runs, along with the average concentrations and mass flow rates for the entire test period.

Table 6. C₁ – C₄ Gaseous Hydrocarbon Emissions.

Compound Name	Measured Concentration (ppb)				Calculated Mass Flow Rate (g/hr)				
	run #1	run #2	run #3	AVG	run #1	run #2	run #3	AVG	SD
Methane	1542.16	621.35	620.00	927.84	547.43	221.35	253.99	340.92	179.58
Ethane	5.17	2.56	4.56	4.10	3.44	1.71	3.50	2.88	1.02
Ethene	63.65	8.22	68.25	46.71	39.51	5.12	48.89	31.17	23.05
Propane	5.41	3.04	3.11	3.85	5.28	2.98	3.50	3.92	1.21
Propene	1.57	0.00	1.29	0.95	1.46	0.00	1.39	0.95	0.82
Butane	2.99	2.59	2.66	2.75	3.85	3.34	3.95	3.71	0.33
Ethyne	3.59	0.00	1.83	1.80	2.07	0.00	1.21	1.09	1.04
2M-Propene	3.69	0.00	0.00	1.23	4.58	0.00	0.00	1.53	2.64

Pittsburg Unit #6 (10/20/00)

5.0 TEST CRITIQUE

CE-CERT originally planned to test Pittsburg Unit #7, a 700 MW generator. Upon arrival at the site and inspection of the sampling location, it was determined that the electric winch system was not operating, and the existing pulley system was inadequate for hauling the numerous pieces of equipment needed at the sample location. After consultation with the

company contact at Southern Energy California, it was decided to test Unit #6, a 400 MW generator.

Due to the dual exhaust configuration, the usual triplicate runs were not conducted. Instead, duplicate consecutive runs were conducted in exhaust duct #1 and a single third run was conducted in exhaust duct #2 (see Figure 5). As the two exhaust ducts are symmetrical in geometry with the vertical stack, it was expected that the effluent flow rates and concentrations would be similar.

The testing and analyses were conducted without any major problems. There is a concern at the Pittsburg Unit #6 facility with the accuracy of the flow rate measurement using the traverse sampling technique. As illustrated in Figure 5, the sampling locations in each exhaust duct are approximately one stack diameter downstream of a 30-degree bend. The sample locations are also approximately one stack diameter upstream of the entrance to the vertical stack. Ideally, the sample location should be at least 8 duct diameters downstream and at least 2 duct diameters upstream of any flow disturbance to ensure fully developed, uniform flow. It is possible that the points that were traversed to determine average stack velocity are not representative of the actual average stack velocity. We were, however, able to traverse 12 equidistant points in each duct, covering the complete cross-section. Other than a couple of “dead spots” along the outside wall (see the results in the Appendix), the measured velocities were fairly uniform. In any case, this should not have a significant effect on the pollutant concentrations measured, but may be a source of error when calculating pollutant mass flow rates using the velocity traverse readings.

6.0 REFERENCES

1. California Air Resources Board, *Methods 1, 2, 3, 4, 100, Source Testing Methods and Procedures*, 1999 Revision.
2. South Coast Air Quality Management District, *Method 5.1 – Determination of Particulate Matter from Stationary Sources*, SCAQMD Source Test Manual, 1997 Revision.
3. EPA 625/R-96/010b, *Compendium Method TO-11A, Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by High Performance Liquid Chromatography (HPLC) [Active Sampling Methodology]*, January, 1999.
4. EPA 625/R-96/010b, *Compendium Method TO-14A, Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Specially Prepared Canisters with Subsequent Analysis by Gas Chromatography*, January, 1999.
5. Siegl, W.O.; Richert, J.F.O.; Jensen, T.E.; Schuetzle, D.; Swarin, S.J.; Loo, J.F.; Probst, A.; Nagy, D.; and Schlenker, A.M. (1993) Improved emissions speciation methodology for Phase II of the Auto/Oil Air Quality Improvement Research Program - Hydrocarbons and Oxygenates. Society of Automotive Engineers International Congress and Exposition Detroit, Michigan, March 1-5.

APPENDIX
Sampling/Analytical Data and Calculations